Statistical Database Generation And Geotechnical Mine Burial Prediction Maps For Coastal Shallow-Water Fine-Grained Sediments

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LONG-TERM GOALS

The ultimate goal is to substantially improve, quantitatively, the U.S. Navy's mine burial predictive capabilities including the Naval Oceanographic Office (NAVO) Mine Warfare operational issues. The goal also is to provide a strong technical basis for the Office of Naval Research (ONR) science program in mine burial prediction basic and applied research (Bennett et al., 1999; Bennett and Wilkens, 2000; Bennett, 2000). The U.S. Navy's capabilities must be substantially improved to meet operational and fleet requirements in mine burial prediction for shallow-water coastal environments. This project is jointly funded by ONR and NAVO.

Comprehensive interrelated sediment geotechnical databases are being developed with empirical relationships that support the developing Expert System (ES) and are crucial to developing a geotechnical mine burial mapping technique based on quantitative sediment properties. The geotechnical, soil physics, and sediment properties approach is essential to quantitatively and statistically evaluate and confidently predict mine burial and predicted depths of burial in shallow-water coastal environments with the ultimate goal of producing mine burial prediction maps.

OBJECTIVES

The objectives are to 1) select two or three shallow-water coastal areas and carry out a comprehensive synthesis of the surficial sediment textural and geotechnical properties of the near shore (≤100 m water depth) environments; 2) conduct a comparative analysis of the geological environments in terms of the sediment properties; 3) develop and analyze the statistical distribution of the sediment and geotechnical properties in terms of the environment(s) of deposition and geological setting; and 4) develop predictive empirical equations of sediment geotechnical properties and mine burial potential with estimates of uncertainty. Based on the geotechnical and sedimentological analyses, mine burial prediction maps will be developed for NAVO using a new approach based on "sediment (soil) state" and natural water contents for selected coastal areas of interest to the U.S. Navy. Data are being prepared for integration in the Expert System.

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Results from research and analysis will provide a basis for developing a geotechnical mine burial prediction methodology based on sediment geotechnical properties (soil physics/sediment behavior, and sediment state/consistency). The applied research will include the development of statistical techniques that correlate sediment types and environments of deposition with selected geotechnical properties (e.g., natural water content and Atterberg limits, shear strength, wet bulk density, etc.). These data will be compiled and integrated with the sediment types to begin establishing "geotechnical signatures" and "classification" of depositional environments for mine burial prediction. This effort supports the ONR-funded Expert System that requires quantitative sediment properties data for impact burial models and mine burial prediction.

APPROACH

Data available in the literature and at SEAPROBE, Inc. are being abstracted and entered into a Master Database (Table 1) for statistical analysis of near shore fine-grained sediment (geotechnical, mass physical and mechanical properties). Selected U.S. coastal areas and other areas selected by NAVO will be used to carry out a comparative study that will quantitatively present sedimentary and geotechnical (engineering) properties in terms of geological environments of deposition and associated sediment types. The thrust is to geotechnically and sedimentologically classify the surficial sediments from each selected area extending from the innermost limit of the shoreline, or from the saltwater/freshwater interface (in the case of estuaries and embayments which extend some distance inland) seaward to depths of approximately 100 meters. The Master Database supports NAVO and the Expert System development by integrating the geotechnical predictors with the NAVO sediment classification (types/classes). An example of the important statistical analyses include relationships among the water-dependent sediment properties, e.g. Liquidity Index, Liquid and Plastic Limits, and Plasticity Index and the natural water content, shear strength, and relationships between the ratio of shear strength to overburden pressure (S_t/P_o) and Plasticity Index (PI) (Skempton, 1954). The effort will include analyses and use of properties such as total organic carbon (TOC), clay mineralogy, and texture (grain size) in relationship to the geotechnical properties for "typing" the coastal depositional environments. Data will be used to construct mine burial prediction maps similar to the demonstration map presented earlier to NAVO and ONR integrating NAVO surficial geology maps with the geotechnical properties data and criteria. The basic research of testing concepts with demonstrations (mine burial prediction technique using "sediment (soil) state") and development of the database for the ES with appropriate statistics is an ONR funded effort, whereas the transition, application, and products of the new mine burial mapping techniques is a NAVO funded effort.

WORK COMPLETED

The Master Database was developed for entering and statistically analyzing the geotechnical/sedimentological properties of selected coastal areas. Data are verified and reconciled with the original source data. This basic and applied research effort was started the last half of FY-03 and significant progress has been made. In addition to many properties listed in Table 1, the following important statistics for the ES are entered in the Master Database:

1) ~600 geotechnical data points for Chesapeake Bay
2) 150 shear strength measurements for Chesapeake Bay
3) ~415 geotechnical data points for selected foreign coastal areas
4) 304 shear strength measurements for selected foreign coastal areas

Data are being collected on the mineralogy, total organic matter, salinity, etc. that will be used to characterize the sediment types and environments of deposition. Selected sediment properties will be used to "type" the geological areas from a geological/sedimentological perspective.

Table 1. GEOTECHNICAL AND SEDIMENTOLOGICAL PARAMETERS FOR THE MASTER DATABASE

Source Key	
Location	Lat.
	Long.
Station	
Sample No.	
Core No.	
Water Depth	(m)
Depth BSF	(cm)
Composition	Siliciclastics
	Carbonates
Texture (%)	Sand
	Silt
	Clay < 4μm
	Clay < 2μm
	Si/Cl
	Sa/(Si + Cl)

Classification	Shepard
	Flemming
	Stevens
Average Grain Density	(g/cm^3)
Median Grainsize, M	(Φ)
	(μm)
Mean Grainsize, M_z	(Φ)
	(μm)
Clay Minerology	Kaolinite
	Illite
	Chlorite
	Smectite
	Other
Wet Bulk Density, γ_t	(Mg/m^3)

Wet Unit Weight,	(lbs/ft^3)
	(kN/m^3)
Dry Unit Weight, γ_d	(kN/m^3)
Porosity, n	(%)
Void Ratio, e	
CaCO3	(%)
OM	(%)
Shear Strength, St	S_u (g/cm^2)
	S_u (kPa)
	S_r (g/cm^2)
	S_r (kPa)
	Cone Penetrometer
	Other
Sensitivity	

Water Content (%)	Dry Weight
	Total Weight
Atterberg Limits	LL (%)
	PL (%)
	PI (%)
	LI (%)
	PI/LL
Casagrande Classification	
Permeability	(cm/s)
Activity	
Percent Saturation	(%)
Percent Gas	(%)
Effective Stress	(kPa)
Comments	

RESULTS

R. Bennett (SEAPROBE, Inc.) developed a new, promising, and simple technique for predicting mine impact burial in fine-grained coastal sediment using selected geotechnical properties (Bennett et al., 1995). The technique has been tested and a demonstration completed based on mine drops, diver measured burial depths, and specific relationships of selected geotechnical properties. A map was developed depicting predicted minimum depths of burial and compared with the actual mine penetration data. Excellent agreement was found between the predicted minimum depths of burial and actual penetration depths. Sediment geotechnical databases are being collected to compare the new mine burial prediction technique with actual measured mine burial depths for different (wide-range) fine-grained sediment types.

IMPACT/APPLICATIONS

The extensive Master Database of coastal sediment geotechnical properties, being developed by SEAPROBE, Inc., will support Expert System requirements being developed by Johns Hopkins University Applied Physics Laboratory. The Expert System is in support of the NAVO mine burial prediction and mine warfare program. Extending the mine burial predictive capabilities based on sediment geotechnical properties and soil physics will greatly enhance the cost effectiveness and past investment that has been committed to developing the NAVO surficial sediment maps produced for several years.

TRANSITIONS

The ultimate long-term aim of the research is to provide extensive data bases to provide the basis for the development of a new model for predicting mine burial in coastal fine-grained sedimentary environments. Additionally, data bases in support of the developing Expert System and the new mine burial prediction model, upon validation, may be entered into the Ocean and Atmospheric Model Library (OAML) for inclusion into Fleet Environmental Tactical Decision Aid (ETDA) systems. At present, the projected ETDA for Mine Countermeasures ships is the Mine Warfare Environmental Decision Aids Library (MEDAL) system developed by N-096 within its Advanced Environmental Acoustics Support (AEAS) Program (6.3). Seafloor and oceanographic environmental data input required by these mine burial prediction models, including *in situ* real-time sediment properties and environmental forcing, and remote sensing capabilities, are developed within the MCM Tactical Environmental Data Systems (MTEDS) and funded by ONR.

RELATED PROJECTS

This project supports the Office of Naval Research, Mine Burial Prediction Science Program, sponsored by the Coastal Geosciences Program, Code 321CG, and supports the Naval Oceanographic Office Warfare Support Branch (N532) ongoing program in Mine Burial Prediction and coastal mapping. The work also has relevance to U.S. Homeland Security.

REFERENCES

Bennett, R.H., Dawn M. Lavoie, William B. Sawyer, Nancy W. Hunter, Michelle M. Meyer, Conrad S. Kennedy, Kingsley H. McCrocklin, Dennis L, Lavoie, and Richard W. Faas, 1995. Geotechnical and Biogeochemical Properties of Sediments from Chesapeake Bay: Mass Physical and Mechanical Properties of Sediments Near the Mouth of the Patuxent River. NRL Report, NRL/PU/7430-95-0008.

Bennett, R.H., R. Dolan, R.W. Faas, L. Maynard, C. Curry, T. Bath, N. Langhorne and C. Butler, 1999. Mine Burial Assessment State-of-the-Art Science, Technology, and Modeling. A Review of Coastal Research, Modeling, and Naval Operational Needs in Shallow Water Environments with Recommendations. SEAPROBE, Inc. Technical Report No. SI-0099-05, 122p. (Restricted Distribution).

Bennett, R. and R. Wilkens, 2000. Mine Burial Prediction Workshop: Technical Program, Agenda, Background, and References, April 5-7, Metairie, LA. SEAPROBE, Inc. Technical Report Number SI-0000-01, 28p.

Bennett, R., 2000. Mine Burial Prediction Workshop Report and Recommendations. SEAPROBE, Inc. Technical Report Number SI-0000-03, 87p.

Skempton, A.W., 1954. Discussion of the Structure of Inorganic Soil. Proceedings-Separate No. 314. The Structure of Inorganic Soil. Proceedings of the Society of Civil Engineering, 80. pp. 478-19 – 478-23.